CHAPTER 9
STREAMBANK STABILIZATION AND RESTORATION

9.1 Introduction

The streams of Fayette County are part of the waters of Fayette County as discussed in Chapter 1. They are shown on the Fayette County GIS waters coverage. The streams of Fayette County are typically those shown on the USGS 7.5 minute quadrangle map with a solid or dashed blue line. However, in some instances streams not shown as blue lines have been found to exhibit the same characteristics as blue line streams and have been added to the Fayette County waters GIS coverage.

In general, streams are:

- natural channels with their size and shape determined by natural forces
- compound in cross section with a main channel for conveying low flows and a floodplain to transport flood flows
- shaped geomorphologically by the long-term history of sediment load and water discharge which they experience

As indicated in Chapter 1, construction is only allowed in the floodplain and stream for certain activities.

The practices listed in this chapter are to be used for two purposes:

- protecting the streambank and floodplain from the construction that must occur
- enhancing the stream and floodplain as part of the overall development or stream restoration plan

9.2 Vegetative Streambank Stabilization

9.2.1 General

In some instances, certain allowable construction will result in excavation into the streambank. In those instances when the natural streambank must be disturbed, first consider vegetative streambank stabilization methods. If those methods are not applicable, use bioengineering techniques. Use structural streambank stabilization techniques as a last resort for permanent stabilization except in instances where a small gabion mattress is needed for outlet protection. In no case will gabions be allowed within a stream unless bioengineering methods are not suitable.

In other instances, increased runoff may cause the deterioration of a natural streambank. Similarly, a natural streambank that has been previously degraded due to past impacts may be further deteriorated by new development. In these cases, the streambank shall be restored to prevent further degradation using vegetative methods and/or bioengineering techniques.

9.2.2 Design Criteria

Planned protective measures shall be compatible with the adjacent land use and the improvements that will be carried out by others.

The selection of native vegetation to be established shall be based on the soil type and chemistry, land use, flooding periods, and stream velocity. A list of recommended species is provided in Table 9-1. Soil tests shall be conducted prior to land disturbance activity to determine if soil amendments and/or fertilizers are needed. If soil tests determine that fertilization is required, then application of recommended fertilizer shall not occur until after the vegetation has germinated and established growth.

Where necessary, erosion control matting or turf reinforcement matting shall be used along with the vegetative measures to stabilize the streambanks.

If traditional vegetative measures described in this section are not effective, bioengineering techniques shall be considered.

Special attention shall be given to maintaining or improving habitat for fish and wildlife.

On smaller streams where a good seedbed can be prepared, herbaceous plants may be used alone to stabilize the banks. On larger streams and more difficult sites, woody shrubs and trees with herbaceous plants shall be considered.

All requirements of state law and permit requirements of local, state, and federal agencies must be met.

9.2.3 Material Specifications

Vegetation shall consist of herbaceous ground cover and/or woody shrubs and trees. Installation methods shall include direct seeding and/or the planting of bare root seedlings, hardwood cuttings, and/or containerized plants.

Direct seeding shall only be conducted during March 1 to May 15 or August 1 to September 30. Bare root and cutting installation shall only be conducted during December 1 to March 15. Installation of containerized plants shall only be conducted during March 1 to May 15 and September 1 to December 31.

The surface shall be mulched with clean wheat straw at a rate of 2 tons per acre. Mulch shall be secured as described in the section on mulch. If mulch tackifiers or related methods are not applicable then erosion control matting or turf reinforcement matting (TRMs) shall be used. Many types of erosion control mats and TRMs are available from various manufacturers. Some are considered temporary because they are manufactured of organic materials that will degrade over time. Due to wildlife endangerment problems associated with the UV resistant mesh in some erosion control matting, only materials with fully degradable mesh shall be used as mulch blankets. Non-degradable products (TRMs) are appropriate where turf reinforcement is necessary. The material shall be chosen based on calculated tractive forces in accordance with manufacturers' recommendations (See Chapter 8).

If nursery stock (bare root or containerized) is used, the species listed in Table 9-1 shall be used for establishing vegetation. Direct seeding of the herbaceous species listed below shall also be used. Selected species shall be based upon the native vegetation of the watershed where work is proposed and shall reflect the original stream bank species. Exotic or pest species shall not be used.

See Section 9.4.2 for recommended species and installation requirements of hardwood cuttings.

9.2.4 Construction Specifications

Prior to seeding or planting, only fallen trees, stumps, and other debris that may force stream flow into the streambank shall be removed. Leaving other debris may be desirable for aquatic habitat.

Where feasible, the streambank side slope shall be cut back to 3:1 slope or flatter and overhanging bank edges shall be removed.

Direct seeding areas shall be roughened with a rake or similar tool. Seeding rates shall be a minimum of 10 lbs. per 1000 square feet of disturbed area.

Erosion control matting or turf reinforcement matting shall be installed in accordance with manufacturers' requirements. Erosion control fabrics, blankets, mats and nettings shall be anchored at the top of streambanks by excavating a shallow trench. The material shall be laid in the bottom of trench with overlap. The trench shall be backfilled with excavated soil. The overlap material shall be laid on top of backfill and secured with dead stout stakes, metal staples, or according to manufacturer's specifications (see Figure 9-1).

Bare root or containerized stock shall be planted at the same depth as planted in the nursery. The stock shall be planted in a hole large enough to accommodate the root system when well spread. Trees and shrubs shall be planted to achieve a minimum density of 300 live stems per acre after three years.

9.2.5 Maintenance

Banks shall be checked after every high water event. Gaps in vegetative cover shall be repaired at once with new plants and mulched if necessary. Exotic and pest species that become established on the bank shall be removed.

TABLE 9- 1
SUGGESTED RIPARIAN SPECIES LIST

The species on the list are only suggestions. Native species that are appropriate for a given site may be proposed.

Tree Species

Pin Oak	*Quercus palustris*
Cherrybark Oak	*Quercus pagoda*
Bur Oak	*Quercus macrocarpa*
Swamp Chestnut Oak	*Quercus michauxii*
Shingle Oak	*Quercus imbricaria*
Northern Red Oak	*Quercus rubra*
Post Oak	*Quercus stellata*
Red Maple	*Acer rubrum*
Green Ash	*Fraxinus pennsylvanica*
Shellbark Hickory	*Carya laciniosa*
Blackgum	*Nyssa sylvatica*
American Elm	*Ulmus americana*
Eastern Cottonwood	*Populus deltoides*
Black Walnut	*Juglans nigra*
River Birch	*Betula nigra*
Yellow Poplar	*Liriodendron tulipifera*
Persimmon	*Diospyrus virginiana*
Black Walnut	*Juglans nigra*
Ohio Buckeye	*Aesculus glabra*
Sugar Maple	*Acer saccharum*
Sycamore	*Plantanus occidentalis*
Persimmon	*Diospyros virginiana*

Shrubs

Arrow-wood	Viburnum dentatum
American Plum	*Prunus americana*
Deciduous Holly	*Ilex decidua*
Gray Dogwood	*Cornus racemosa*
Silky Dogwood	*Cornus amomun*
Spicebush	*Lindera benzoin*
Sassafrass	*Sassafras albinum*
American Elder	*Sambucus canadensis*
Button Bush	*Cephalanthus occidentalis*
River Cane	*Arundinaria gigantea*
Coralberry	*Symphoricarpos orbiculatus*

Herbaceous Species

Rice cutgrass	*Leersia oryzoides*
Managrass	*Glyceria striata*
Spangle grass	*Chasmanthium latifolium*
Barnyard grass	*Echinochloa crus-galli*
Switchgrass	*Panicum virgatum*
Annual rye	*Secale cereale*
Wild rye	*Elymus virginicus*
Deertongue grass	*Panicum clandestinum*
Panic grass	*Panicum microcarpon*
Giant Cane Bambo	*Arundinaria gigantea*
Boneset	*Eupatorium perfoliatium*
Big Bluestem	*Andropogon gerardii*
Prairie cordgrass	*Spartina pextinata*
Water Plantain	*Alisima subcordatum*
Common Milkweed	*Asclepias syracia*
Beggar's Ticks	*Biden polyeps*
Canada Brome	*Bromus pubescens*
American Bellflower	*Campanula americana*
Frank's Sedge	*Carex frankii*
Sedge	*Carex granularis*
Shallow Sedge	*Carex lurida*
Hop Sedge	*Carex lupulina*
River Oats	*Chasmanthium latifolium*
Riverbank Wild rye	*Elymus riparius*
Downy Wild rye	*Elymus villosus*
Joe-pie Weed	*Eupatorium maculatum*
Fowl Manna Grass	*Glyceria striata*
Rush	*Juncus sp.*
Western Panic grass	*Panicum acuminatum*
Switchgrass	*Panicum virginica*
Foxglove Beardtongue	*Penstemon digitalis*
Leafcup	*Polymnia canadensis*
Brown-eyed Susan	*Rudbeckia triloba*
Dark Green Bulrush	*Scirpus cyprinus*
Yellow Wingstem	*Verbesina alternafolia*
White Wingstem	*Verbesina virginica*

9.3 Riparian Buffer Zones

9.3.1 General

Riparian buffer zones are areas of trees and/or shrubs located adjacent to and up-gradient from perennial or intermittent streams, lakes, ponds, wetlands, and areas with groundwater recharge. They may be constructed by Developers to satisfy some or all of the required water quality volume (see Chapter 10).

The purpose of riparian buffer zones are:

- to reduce excess amounts of sediment, organic material, nutrients, pesticides, and other pollutants in surface runoff and reduce excess nutrients and other chemicals in shallow groundwater flow
- create shade to moderate water temperatures to improve habitat for fish and other aquatic organisms
- to provide a source of detritus and large woody debris for fish and other aquatic organisms
- to provide riparian habitat and corridors for wildlife

9.3.2 Design Criteria

The buffer shall consist of a zone (identified as Zone 1) that begins at the top of bank, and extends a minimum distance of 15 feet, measured horizontally on a line perpendicular to the water course or water body and planted with tree species selected from Table 9-1.

An additional strip or area of land (Zone 2) will begin at the edge and up-gradient of Zone 1 and extend a minimum distance of 20 feet, measured horizontally on a line perpendicular to the water course or water body. Zone 2 shall be planted with shrubs and herbaceous ground cover species selected from Table 9-1. The combined width of Zones 1 and 2 shall be 100 feet or 30 percent of the geomorphic floodplain, whichever is less. A geomorphic floodplain is defined as the area adjacent to a river or stream that is built of alluvial sediments that are associated with the present depositional activity.

Figures 9-1 and 9-2 illustrate examples of Zone 1 and 2 widths for water courses and water bodies. Zone 2 may need to be adjusted to include important resource features such as wetlands, steep slopes, or critical habitats.

Buffers shall be established or maintained from top of bank to waterline along water courses and bodies where practical. The buffer canopy shall be established to achieve at least 50 percent crown cover with average canopy heights equal to or greater than the width of the water course, or 30 feet for water bodies. (See Figure 9-3).

Dominant vegetation shall consist of existing or planted trees and shrubs suited to the site and the intended purpose. Selection of locally native species shall be a priority when feasible. Plantings shall consist of six or more species in an attempt to achieve greater diversity. Individual plants selected shall be suited to the seasonal variation of soil moisture status of individual planting sites. Plant types and species shall be selected based on their compatibility in growth rates and shade tolerance.

Necessary site preparation and planting for establishing new buffers shall be done at a time and manner to insure survival and growth of selected species. Refer to Section 9.2 for care, handling, and planting requirements for woody planting stock.

Only viable, high quality, and adapted planting stock shall be used. The method of planting for new buffers shall include hand or machine planting techniques, suited to achieving proper depths and placement for intended purpose and function of the buffer.

Site preparation shall be sufficient for establishment and growth of selected species and be done in a manner that does not compromise the intended purpose. Refer to Section 9.2 for woody planting stock quality requirements and planting rate densities. Supplemental moisture shall be applied if and when necessary to assure early survival and establishment of selected species.

Livestock shall be controlled or excluded as necessary to achieve and maintain the intended purpose. Water course crossings and livestock watering shall be located and sized to minimize impact to buffer vegetation and function.

9.3.3 Maintenance

The riparian forest buffer shall be inspected periodically, protected, and restored as needed, to maintain the intended purpose and protect it from adverse impacts such as excessive vehicular and pedestrian traffic, pest infestations, pesticide use on adjacent lands, livestock damage, and fire.

Replacement of dead trees or shrubs and control of undesirable vegetative competition shall be continued until the buffer has reached, or will progress to, a fully functional condition.

To maintain buffer function, control of erosion and sedimentation shall be continued in the upgradient area immediately adjacent to Zone 2 until the upgradient area is permanently stabilized.

For purposes of moderating water temperatures and providing detritus and large woody debris, riparian forest buffer management must maintain a minimum of 50 percent canopy cover. To achieve benefits provided by large woody debris, natural mortality of trees and shrubs may need to be supplemented by periodically falling and placing selected stems or large limbs within water courses and water bodies

9.4 Bioengineering Techniques

Bioengineering techniques for streambank protection utilize native vegetation in combination with inert structural materials to stabilize soils that are subject to erosion and shallow mass movement.

9.4.1 Design Criteria

Establishing permanent vegetation is the preferred method for stabilizing soils along streambanks. With proper installation and maintenance, the planting of rooted stock, cuttings and direct seeding of native vegetation, in combination with erosion control fabrics, will effectively stabilize soils on slopes of 3:1 or flatter along streams with low flows and no concentrated discharges over the face of the streambank.

On streambank slopes of 3:1 or steeper, the techniques described in the following sections (with exception of the Live Staking technique) shall be employed as needed. Each technique is discussed in order of increasing effectiveness of protection based upon the slope of the streambank. The combined use of two or more techniques to accomplish streambank stabilization and protection may be applicable for some sites.

When streambanks must be disturbed, slopes shall be regraded to match the adjoining upstream and downstream slopes, if they are stable. If the adjoining slopes are not stable, the disturbed portion shall be regraded to the least gradient possible.

Reinforcement shall be provided at the base or toe of the streambank below the mean low waterline prior to implementing bioengineering techniques. Several techniques discussed are applicable for base reinforcement. All work shall begin at the base of the streambank and continue up gradient.

For sites involving the discharge of concentrated flow through a streambank and directly into a stream, protection shall be provided for the streambank opposite of the concentrated discharge. Most of the techniques discussed below will be applicable for those sites and are duly noted.

9.4.2 Live Stake

Live stakes shall be used in limited situations for streambank slopes of 3:1 or flatter with low flows and no surficial overbank discharge. This technique consists of inserting (tamping) fresh hardwood cuttings into the streambank. This technique is more applicable as a preventive measure before severe erosion problems occur.

Live hardwood cuttings shall be collected and installed during the dormant season (November through March) from areas near the site. Drainage ditches, detention ponds, and construction sites can be good sources for materials. The following table provides recommended species for hardwood cuttings. Table 9-1 provides the recommended species for rooted seedlings.

TABLE 9- 2
NATIVE PLANT SPECIES SUITABLE FOR HARDWOOD CUTTING IN CENTRAL KENTUCKY

Common Name	Scientific Name
Primary Species:	
Black willow	*Salix nigra*
Sandbar willow	*Salix interior*
Heart-leaf willow	*Salix rigida*
Silky dogwood	*Cornus amomum*
Redosier dogwood	*Cornus sericea*
American elderberry	*Sambucus canadensis*
Secondary Species:	
Tall pussy willow	*Salix discolor*
Silky willow	*Salix sericea*
Dwarf willow	*Salix humilis var. macrophylla*
Alternate-leaf dogwood	*Cornus alternifolia*
Gray dogwood	*Cornus racemosa*
Rough-leaf dogwood	*Cornus drummondii*
Boxelder	*Acer negundo*
Nannyberry	*Viburnum lentago*
Swamp Haw	*Viburnum nudum*
Arrowwood	*Viburnum dentatum*

Other practices, in combination with live stakes, shall be used for streambanks that receive high flow fluctuations or consist of fill soils.

Stakes (cuttings) shall be 2 to 3 feet in length and 0.5 to 2 inches in diameter with all outer branches removed. Basal end (inserted into ground) shall be sawed clean at an angle. Blunt end (exposed end) shall be cut square. See Figure 9-4A for a live stake detail.

Stakes shall be installed within 24 hours of cutting. Temporary storage shall occur in a moist, cool location.

Stakes shall be installed at right angles to the slope with 20 percent (1/5) of the stake left exposed. Stakes shall be spaced at a minimum of 2 to 4 per square yard and in a random configuration.

Installation shall begin at the base of the streambank working up gradient. Dead blow hammers work the best for installing stakes in soft soils. In cases where stiff soils exist, then pre-drilled holes must be used to accommodate cutting installation. The ground at the base of each stake shall be tamped firm.

When erosion control fabrics are necessary, the live stakes shall be used to help secure the material to the face of the streambank.

9.4.3 Root Wad Revetment

Root wad revetment techniques can be used for opposite bank protection from concentrated flow discharge and as toe of slope reinforcement with a high flow fluctuation in the stream. This technique is excellent for restoring and improving fish habitats and, when used in combination with proper vegetative methods, is highly effective for stabilizing streambanks.

Root wads are tree stumps with a minimum of 6 feet of bole (trunk) above the root flare. The root wads shall be built on top of footer logs and secured with a header log. Footer and header logs shall be secured to the root wad by iron rebar. The bole shall be inserted or placed in the bank at a 30 to 45 degree angle from the downstream line of streamflow, i.e. the root flare shall face upstream.

Placed stone shall be used to further secure the root wad system. Filter fabrics may be required in loamy silts or sandy soils.

Root wads shall be backfilled with soil and planted with live stakes. Streambank above root wad shall be covered with erosion control fabrics and planted. Figure 9-5 shows the typical construction detail for root wad revetment.

9.4.4 Coir Log Revetment

Coir (coconut fiber) log revetments can be used for slope stabilization at the toe of slopes of 2:1 or flatter and as protection for streambanks opposite concentrated discharge points. Coir log revetments shall be used in combination with coir mats or jute netting, planted vegetation and/or live staking. Figure 9-6 provides a detail of staked coir log revetment.

Coir logs shall be secured with dead stout stakes inserted down gradient and against logs. Live stakes should be inserted directly into logs. Coir twine should be wrapped around dead stout stakes and over logs to hold them securely to the bank face.

Dead stout stakes are 2.5 feet long and 2 inches thick by 4 inches wide (2x4) of <u>untreated</u> lumber that have been cut diagonally across the 4 inch width with a 0.25 inch tip. Figure 9-4B shows in detail how the stakes are cut.

9.4.5 Live Fascine

The live fascine technique is applicable on slopes of 2:1 or flatter and utilizes cylindrical bundles of freshly cut willow (*Salix spp*.), or dogwood (*Cornus spp*.) branches placed in trenches excavated along the contours of the streambank. Live fascines can also be used to reinforce the toe of streambank slopes.

Fascines shall not be used when surficial concentrated flows are discharged over the face of the streambank or where high flow fluctuations occur. When used in combination with coir mats or jute netting and planted vegetation, live fascines can be used on slopes of 2:1 or flatter.

Coir logs shall be used in place of live fascines when bundle materials are not available; however, the coir logs shall be planted with rooted willow, dogwood, or alder.

Live fascine bundles can be 5 to 30 feet in length by 7 to 10 inches in diameter and tied together with jute or bailing twine. The bundles are secured with both dead stout stakes and live stakes of fresh cut willow.

The cuttings are composed of branches 0.5 to 1 inch in diameter and must be arranged in the bundle with growing tips in the same direction and staggered to evenly distribute growth along the bundle. See Figure 9-7 for construction detail.

Small trenches (12 inch by 12 inch) shall be constructed starting at the base of the slope, parallel to the stream channel, and spanning the entire streambank. Parallel trenches shall be constructed along the face of the slope according to the following table:

TABLE 9- 3
LIVE FASCINE TRENCH DISTANCES

Bank Slope	Slope Distance Between Trenches	Maximum Slope Length
2:1 to 2.5:1	5 to 6 feet	20 feet
2.5:1 to 3:1	6 to 7 feet	30 feet
3:1 to 3.5:1	7 to 8 feet	40 feet
3.5:1 to 4:1	8 to 9 feet	50 feet

Source: Wright, 1995.

Live fascines shall be placed end to end inside the trenches starting at the base of the slope and working up gradient. Dead stout stakes shall be tamped into bundles every 3 feet along the length and at bundle connections. Trenches shall be backfilled with soil and tamped firm around the fascine.

Live stakes shall be tamped in down gradient and against the bundles at right angles to the slope. The live stake procedures in Section 9.4.1 shall be used.

9.4.6 Brush Mattress

Brush mattresses are applicable for 1:1 slopes or flatter along streams subject to high flow fluctuations. They can also be used for opposite streambank protection. This technique is limited to streambank faces of 10 feet or less. Brush mattresses require substantial amounts of materials, which including live fascines, live stakes, dead stout stakes, and cut branches.

The slope face shall be prepared by smoothly grading the surface and constructing a small trench (12 inch by 12 inch) at the base of the slope, parallel to the stream channel, and spanning the entire streambank.

Live fascines shall be installed in the trench as described in Section 9.4.4.

Dead stout stakes shall be installed 3 feet on center in rows parallel to the channel for the entire slope face. Six inches of stake shall be left exposed above the surface. Figure 9-8 shows in detail the layout of the trench and stakes.

Pieces of willow and/or dogwood cuttings 8 – 10 feet long shall be placed along the bank with basal ends towards the trench. Enough brush shall be used to create a 6-inch thick mattress.

The mattress shall be secured by wrapping wire or coir rope around dead stout stakes in a criss cross pattern between stakes. Work shall begin at bottom of the slope and proceed upgradient.

The stakes shall be tapped further into ground to secure the mattress to the bank face. Live stakes shall be inserted between dead stout stakes similar to Section 9.4.1.

Cover area lightly with soil and tamp. Do not bury branches.

9.4.7 Branch Packing

Branch packing consists of alternating layers of live willow and/or dogwood cuttings and compacted soil secured with wooden poles along a trench. Branch packing is applicable for slopes of 1:1 or flatter that receive surficial discharge over the face of the streambank and high flow fluctuations in the stream channel. This technique can also be used for opposite streambank protection and in areas where severe erosion has resulted in shallow mass movement of the streambank.

The trench dimensions for this technique are limited to 12 feet long by 5 feet high and 4 feet deep. Biodegradable filter fabrics shall be used to reinforce soil layers along streams with high flow fluctuations. Placed stone or log cribs shall be used for toe of slope reinforcement at mean low waterline. See Figure 9-9 for a detail on this technique.

Wooden poles (4 inches in diameter) shall be <u>untreated</u> and cut at lengths to accommodate the specific depth of the site plus 4 feet. Branch cuttings shall be cut to lengths to accommodate the depth of trench plus 3 feet.

The trench shall be excavated clean and the bottom of the site sloped towards the bank from the stream channel. A stone or log crib shall be placed at the outer edge of the excavated area into and below mean low waterline.

Dead stout stakes shall be inserted 4 feet deep into the bottom of the trench on 1.5-foot centers. The first layer of brush shall be placed in the bottom of the trench with basal ends towards the bank in a criss-cross pattern 6 inches thick. The first brush layer shall be backfilled with 12 inches of equal parts soil and large gravel. The soil/gravel layer shall be compacted.

This process shall be repeated until the trench is filled. The amount of rock mixed with the soil can be reduced with each successive layer. The compacted bank face should correspond to the adjoining streambank slopes.

9.4.8 Live Cribwall and Log Crib Revetment

Live cribwalls are rectangular frameworks of logs or timbers backfilled with soil, rock and live branch cuttings. They are applicable for a bank of any gradient that receives surficial discharge over the bank and high flow fluctuations and where space is limited to stabilize the streambank.

This technique is limited in overall height of 6 feet and shall <u>not</u> be used where the adjoining streambed is subject to severe degradation. Figure 9-10 shows a detail for live cribwall.

Branch cuttings shall be 0.5 to 2 inches in diameter and 4 to 6 feet long. Logs or timbers shall be 4 to 6 feet long in varying lengths to accommodate site conditions. Timber shall be <u>untreated</u>. Stone shall be 2 to 4 inches in diameter.

The work area shall be over excavated 2 to 3 feet below the streambed or toe of bank and sloped back towards bank. Long log or timber shall be placed parallel to the channel and then short logs placed on top and perpendicular. Short logs shall extend to the back of the work area (bank). The logs shall be secured with rebar or spikes. This layer shall be backfilled, covered with 12 inches of rock, and compacted.

Build successive layers using rock as backfill until cribwall is above mean low waterline. Use soil backfill in layers above mean low waterline. Compact each soil layer.

The layer building process shall be repeated placing live brush cuttings on top of each compacted soil layer. The cuttings shall be placed with basal end towards the bank and the growth ends protruding out from the cribwall.

The slope of cribwall shall correspond to the adjoining streambank slope and the final layer shall reach to the top of the original streambank not to exceed 6 feet in overall height.

Log crib revetment techniques can be very effective for opposite bank protection or toe of bank reinforcement, especially where high concentrated discharges and high stream flow fluctuations occur. They are similar in construction to live cribwalls with the exception that they are lower in height and no vegetation is used. See Figure 9-11 for a construction detail.

9.4.9 Joint Planting

Joint planting is applicable to sites where the use of gabion mattresses or rubble stone to stabilize a streambank has been determined to be the only practical method. This technique is accomplished by inserting live willow stakes between the placed stone. This technique is also applicable where stone is used for toe of bank reinforcement.

Willow tree species are the best for live cutting and shall be a minimum length of 3 to 3.5 feet and 1 to 2 inches in diameter. Planting time and storage specifications are similar to live staking.

The stakes shall be inserted in random configuration at a spacing of 3 to 6 stakes per square yard. At least two thirds of the stakes shall extend in to the soil below the stone layer.

9.4.10 Maintenance and Monitoring

Streambanks shall be checked after every high water event for six months after completion. Noticeable failures in bioengineering techniques shall be repaired as necessary. Vegetation growth shall be monitored for one year after completion to determine survival rates of planted vegetation. A minimum of 75 percent of designed density must be established by end of the first year after completion. Volunteer species will be considered towards the survival density. Areas of erosion or undermining of streambank adjoining the stabilized portion of the stream shall be noted and monitored to assess whether retrofitting or repairs will be needed.

Signs shall be posted indicating a natural area that should not be mowed.

9.5 Structural Streambank Stabilization

Structural stream-bank stabilization refers to the stabilization of banks of live steams with permanent structural measures. Generally, the materials and processes are proprietary and include things like interlocking concrete blocks, gabions, gabion mattresses, crib walls, synthetic cellular confinement grids, and dry stone masonry.

9.5.1 Design Criteria

Structural stream-bank stabilization shall be used only in cases where vegetative stabilization in conjunction with turf reinforcement matting and vegetative bioengineering will not be effective.

Structural stabilization measures shall be planned and designed by an engineer and shall be used, only as necessary, in conjunction with vegetative techniques.

Rip-rap may be used if other measures are not feasible.

The protective measures shall be compatible with improvements planned or being carried out by others. The bottom scour shall be controlled before any permanent type of bank protection can be considered feasible unless the protection can be safely and economically constructed to a depth well below the anticipated lowest depth of bottom scour.

Streambank protection shall start and end at a stabilized or controlled point on the stream.

Changes from a natural channel alignment shall not generally be made. Alignment changes in previously modified channels shall be made to take the channel to a more natural alignment and shall consider the effect upon land use, hydraulic characteristics, and the existing channel.

Special attention shall be given to maintaining and improving habitat for fish and wildlife.

Structural measures must be effective for the design flow and be capable of withstanding greater flows without serious damage.

All requirements of state law and permit requirements of local, state, and federal agencies must be met.

9.5.2 Specifications

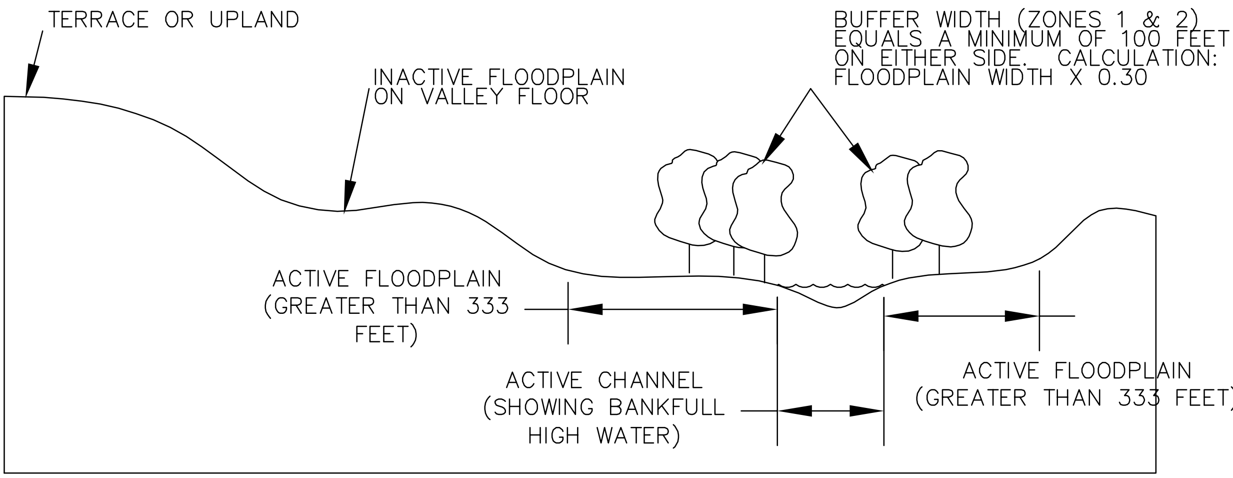
All structural stream-bank protection measures shall be designed and installed in accordance with manufacturer's standards and specifications.

9.5.3 Maintenance

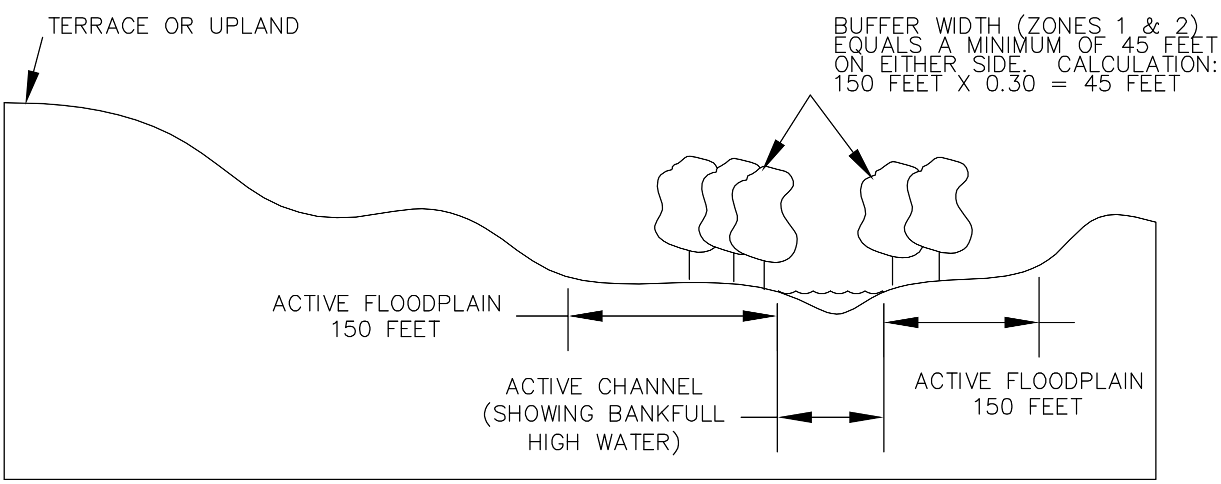
All structures shall be maintained in an "as built" condition. Inspection shall occur each month for the first 6 months after construction and at least every 6 months thereafter. Structural damage caused by storm events shall be repaired as soon as possible to prevent further damage to the structure or erosion of the streambank.

FIGURE 9-1

RIPARIAN BUFFER ZONE WIDTHS
ACTIVE FLOODPLAIN ON
BOTH SIDES OF CHANNEL
(EFFECTIVE DATE 1/01/09)



ACTIVE FLOODPLAINS GREATER THAN 333 FEET IN WIDTH



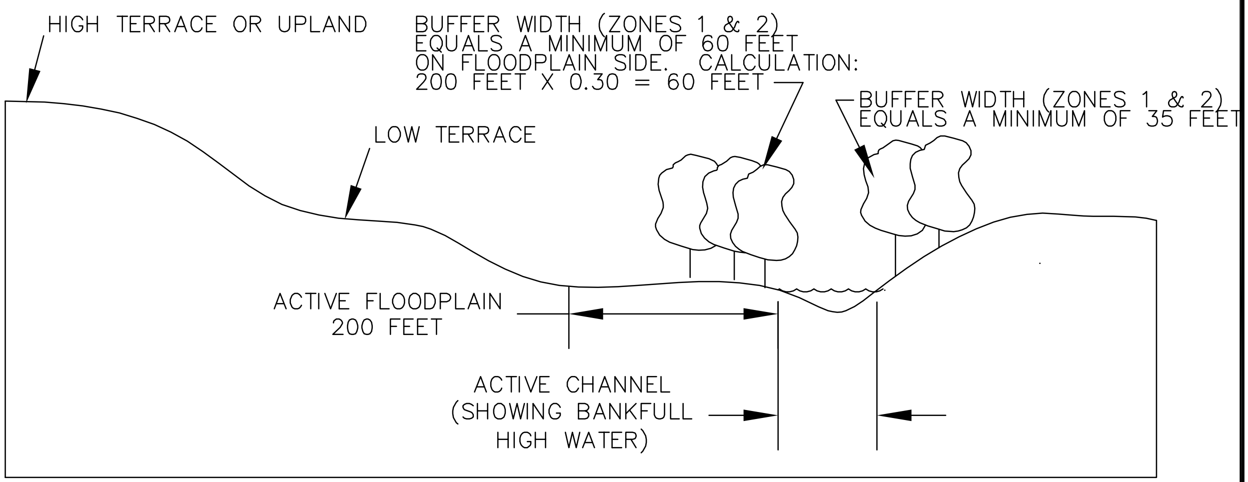
ACTIVE FLOODPLAINS LESS THAN 333 FEET IN WIDTH

STORMWATER MANUAL

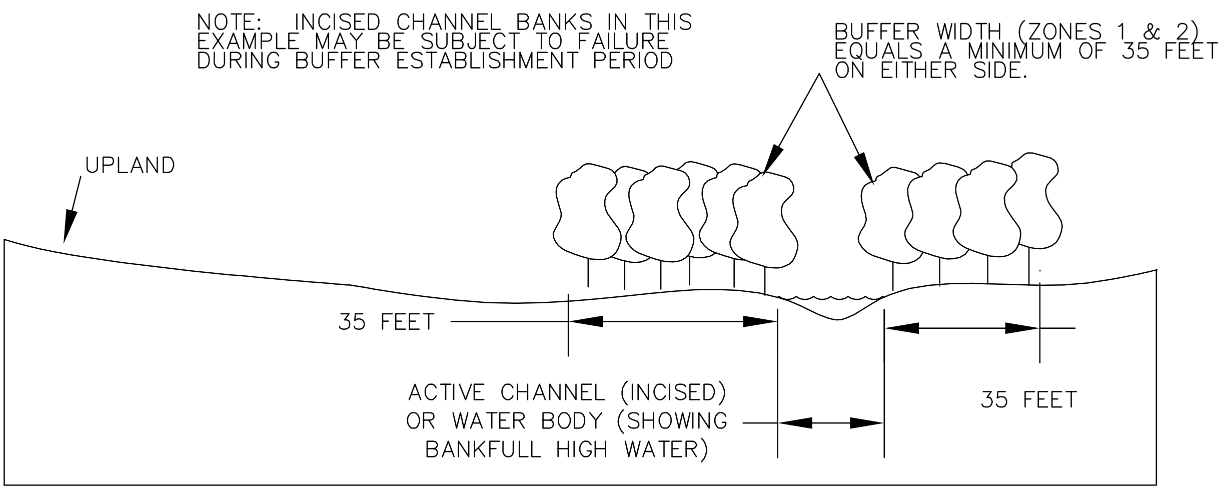
FIGURE 9-2

OTHER RIPARIAN BUFFER ZONE WIDTHS

(EFFECTIVE DATE 1/01/09)



ACTIVE FLOODPLAIN ONLY ONE SIDE OF THE CHANNEL

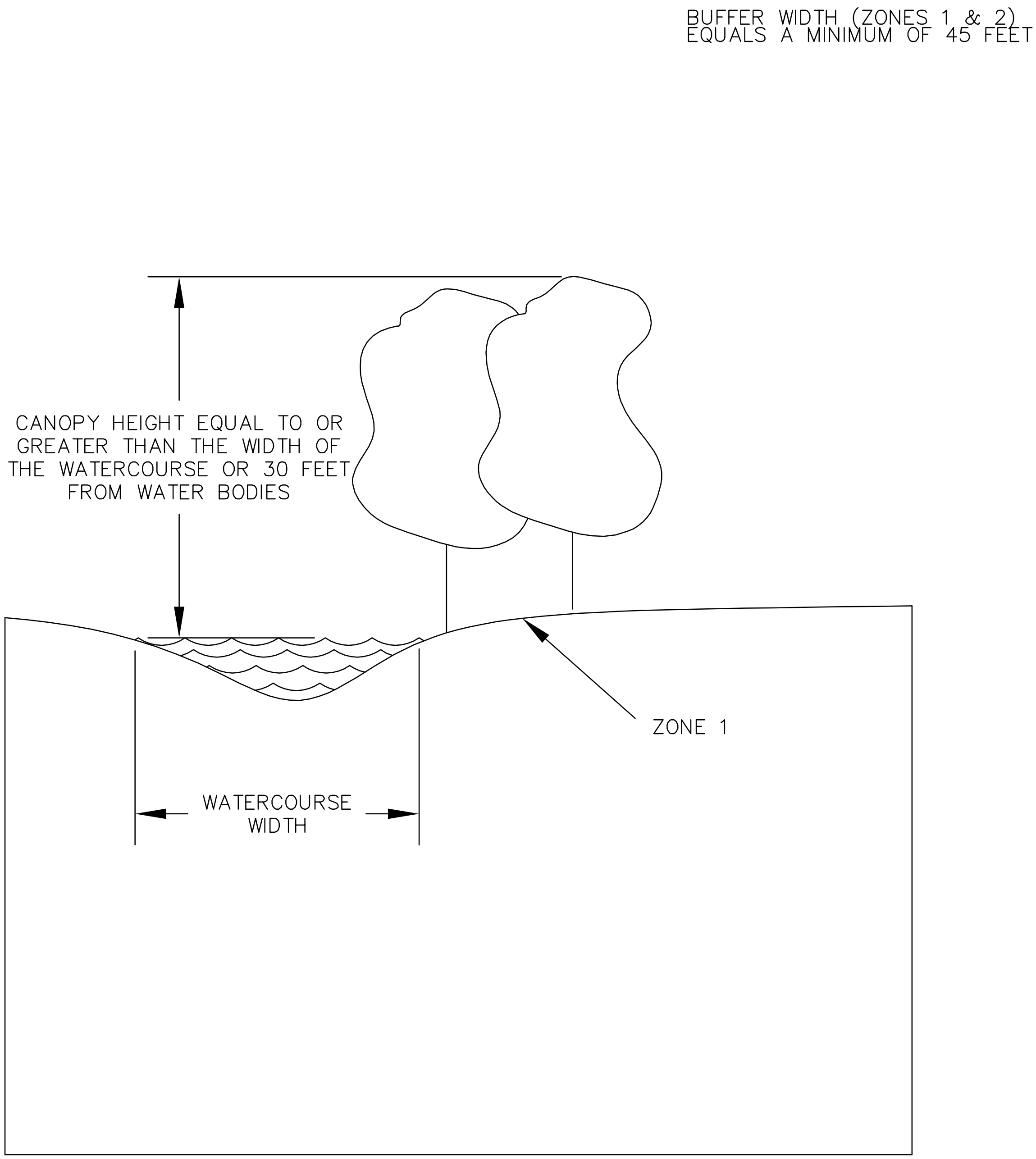


INCISED CHANNEL WITHOUT FLOODPLAINS AND ALL WATER BODIES

STORMWATER MANUAL

FIGURE 9-3

CANOPY HEIGHT
FOR WATER TEMPERATURE CONTROL
(EFFECTIVE DATE 1/01/09)

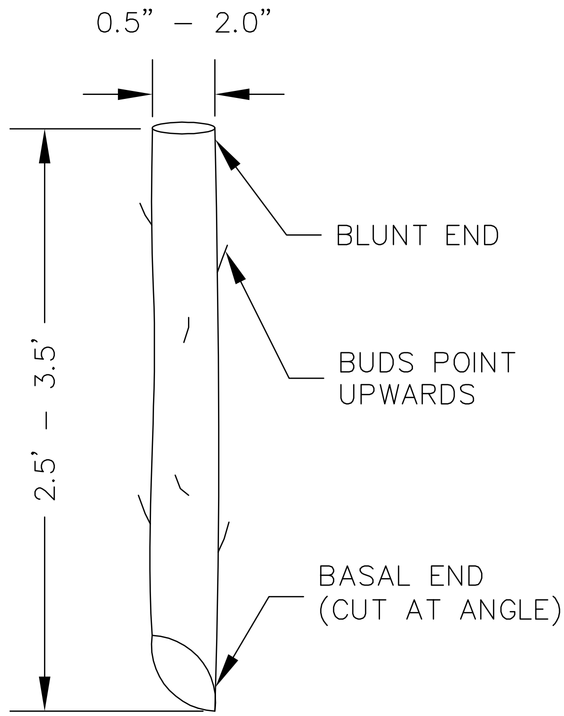


STORMWATER MANUAL

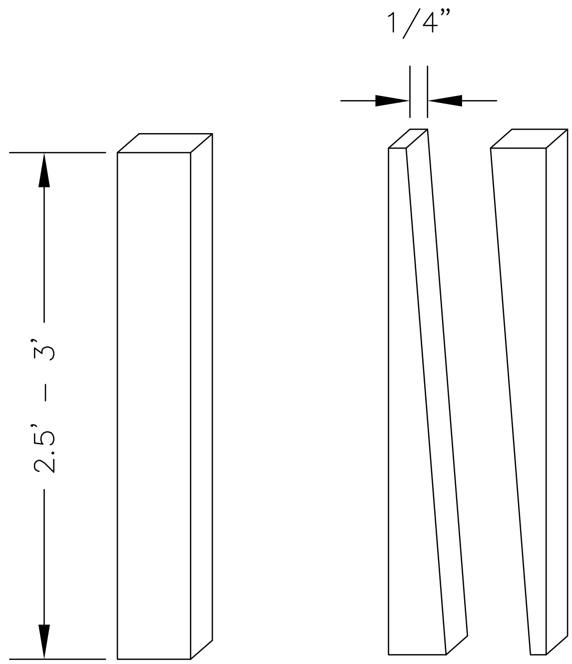
FIGURE 9-4

DETAILS OF STAKES

(EFFECTIVE DATE 1/01/09)



A. LIVE STAKE



B. DEAD STOUT STAKE

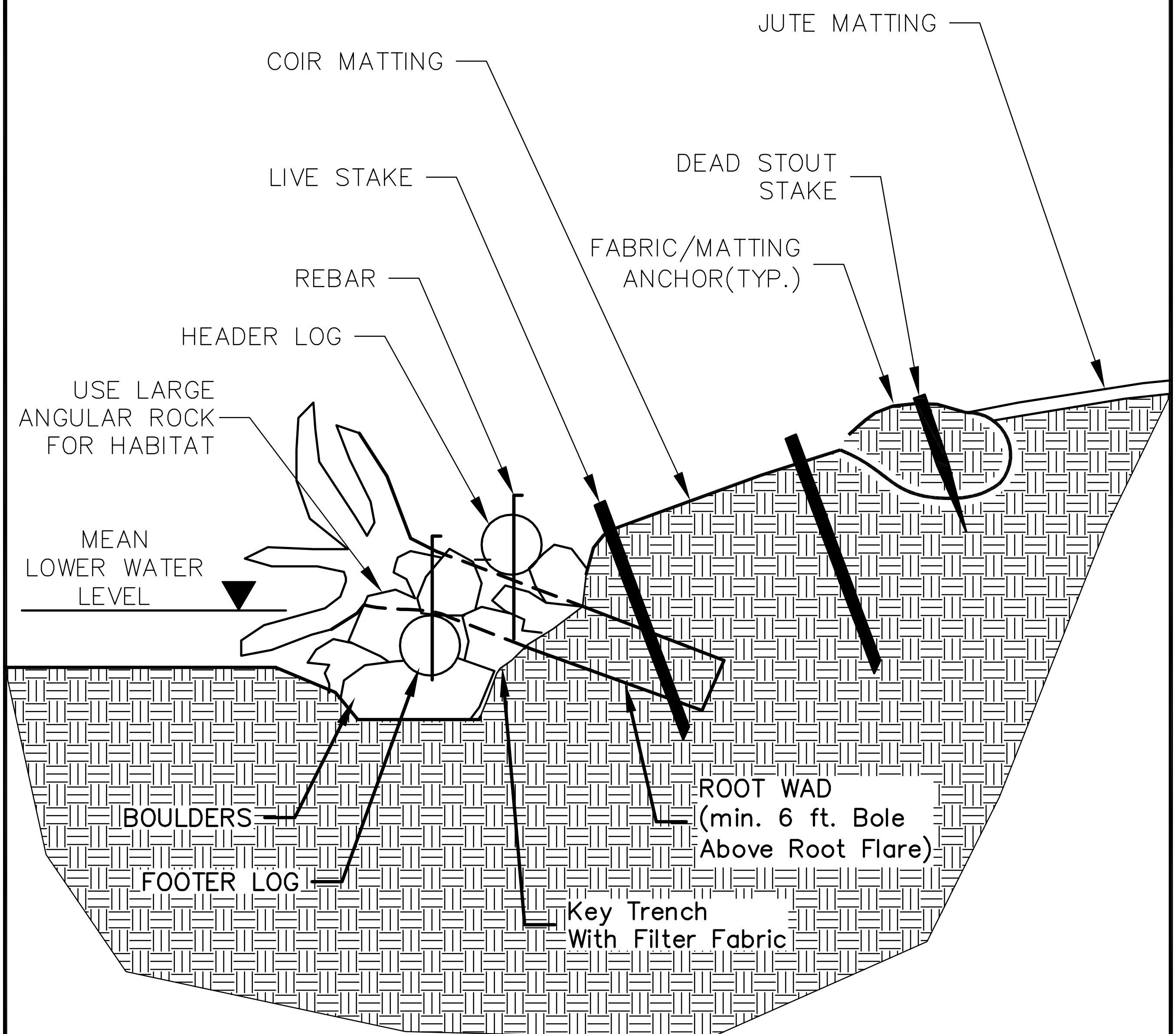
SAW 2X4 TIMBER DIAGONALLY TO PRODUCE 2 DEAD STOUT STAKES

STORMWATER MANUAL

FIGURE 9-5

DETAIL OF ROOT WAD REVETMENT

(EFFECTIVE DATE 1/01/09)



SECTION VIEW

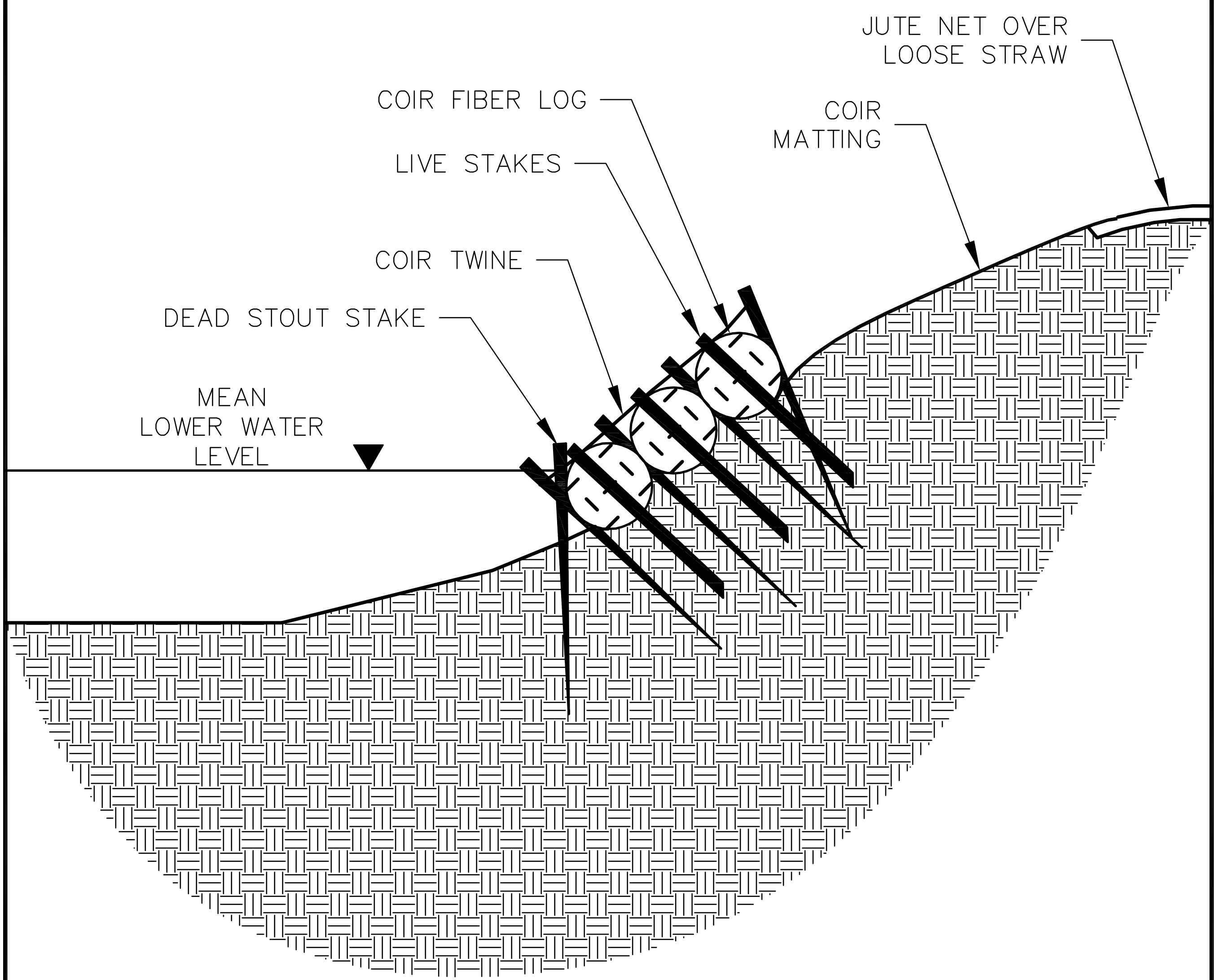
N.T.S.

STORMWATER MANUAL

FIGURE 9-6

DETAIL OF STACKED COIR FIBER LOG REVETMENT

(EFFECTIVE DATE 1/01/09)



SECTION VIEW

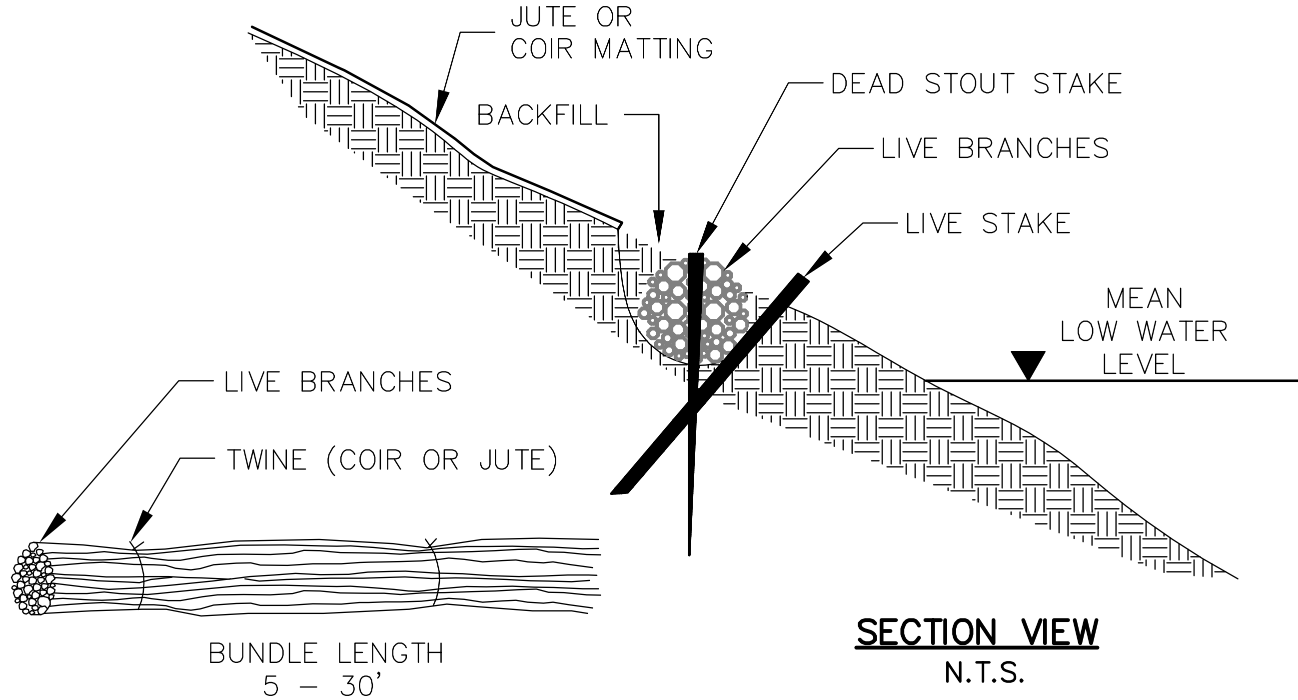
N.T.S.

STORMWATER MANUAL

FIGURE 9-7

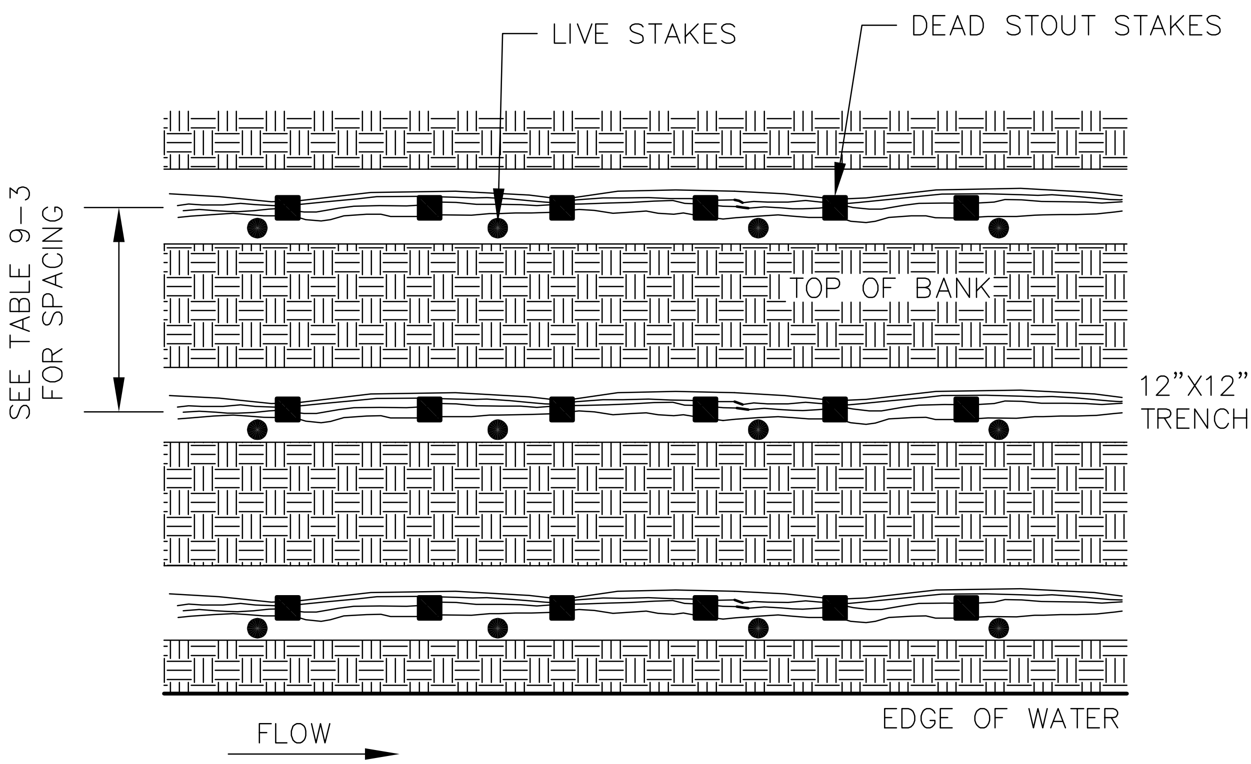
DETAIL OF LIVE FASCINE

(EFFECTIVE DATE 1/01/09)



SECTION VIEW

N.T.S.



PLAN VIEW

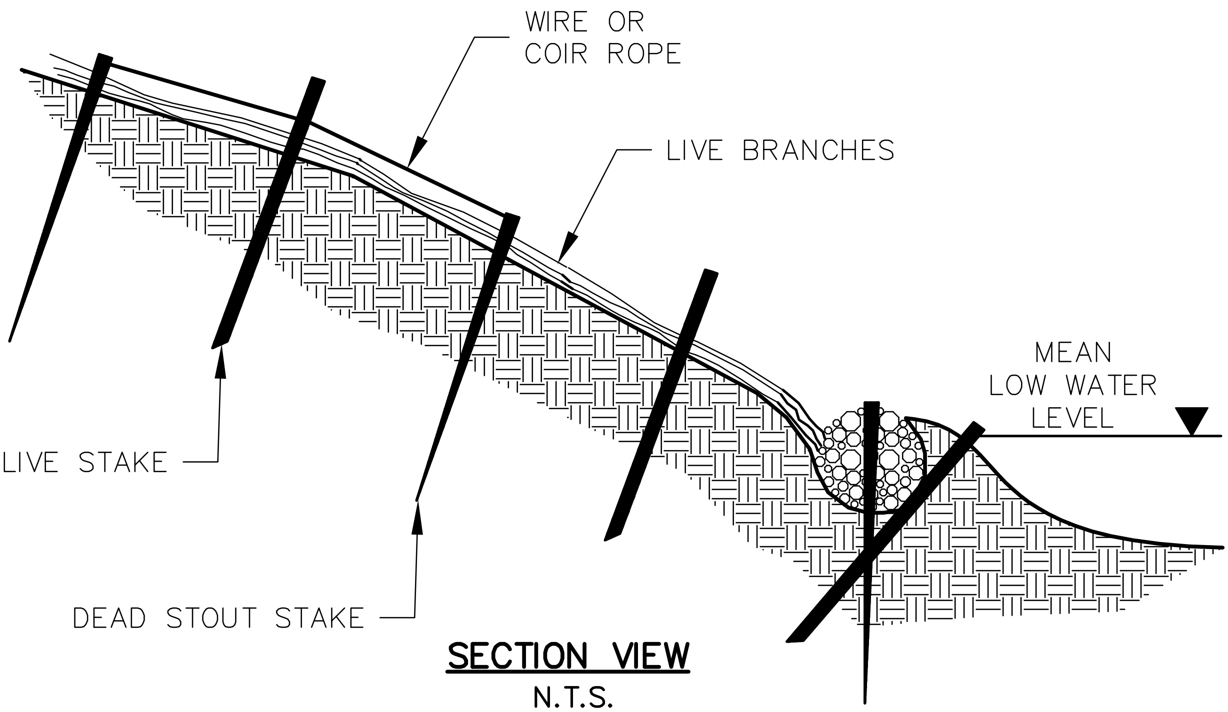
N.T.S.

STORMWATER MANUAL

FIGURE 9-8

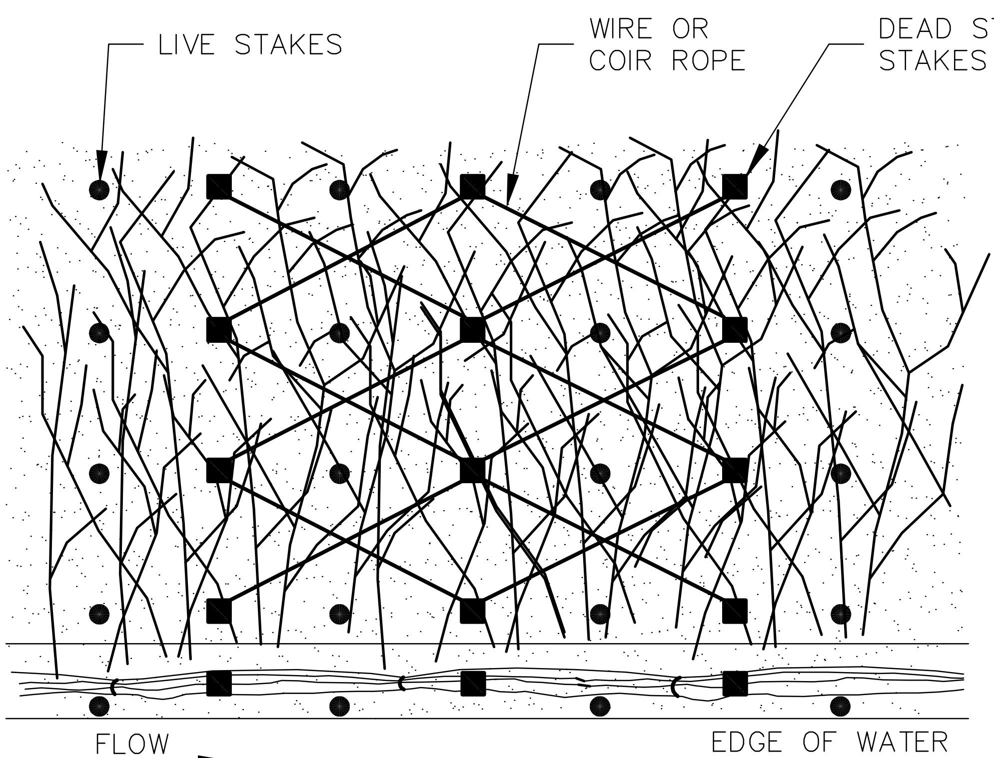
DETAIL OF BRUSH MATTRESS

(EFFECTIVE DATE 1/01/09)



SECTION VIEW

N.T.S.



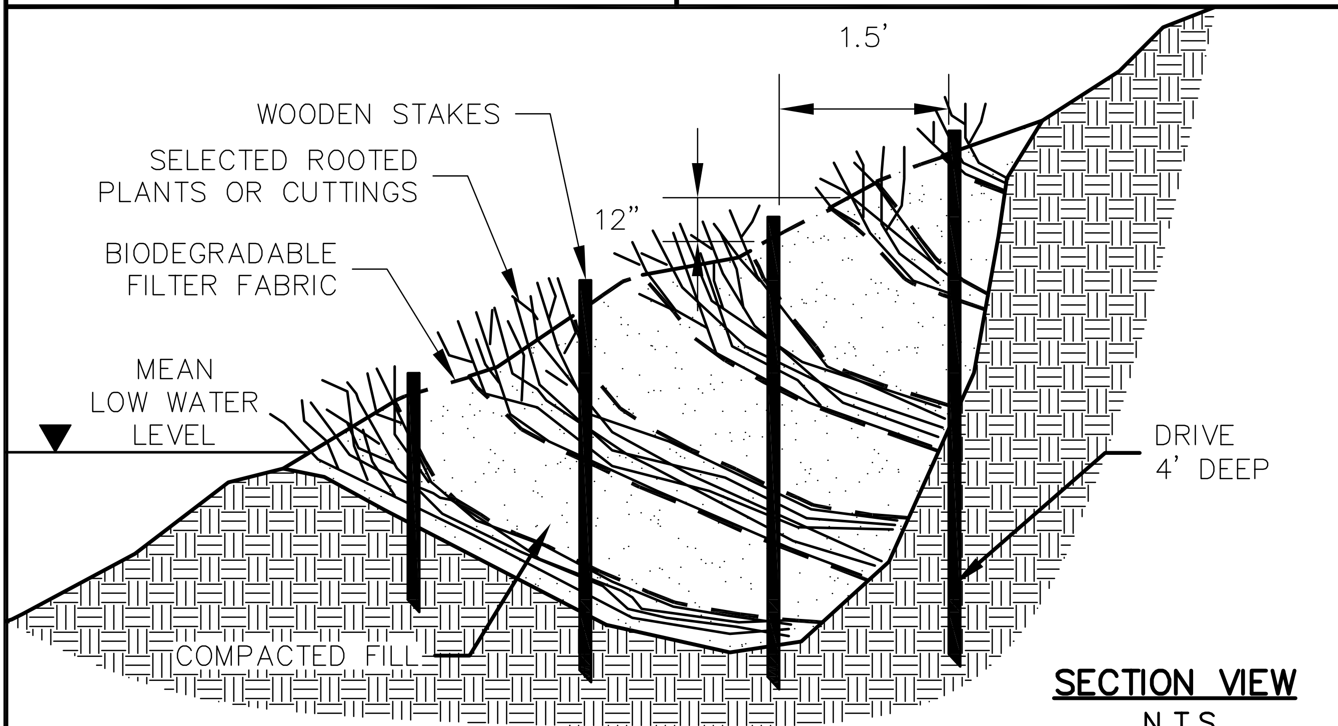
PLAN VIEW

N.T.S.

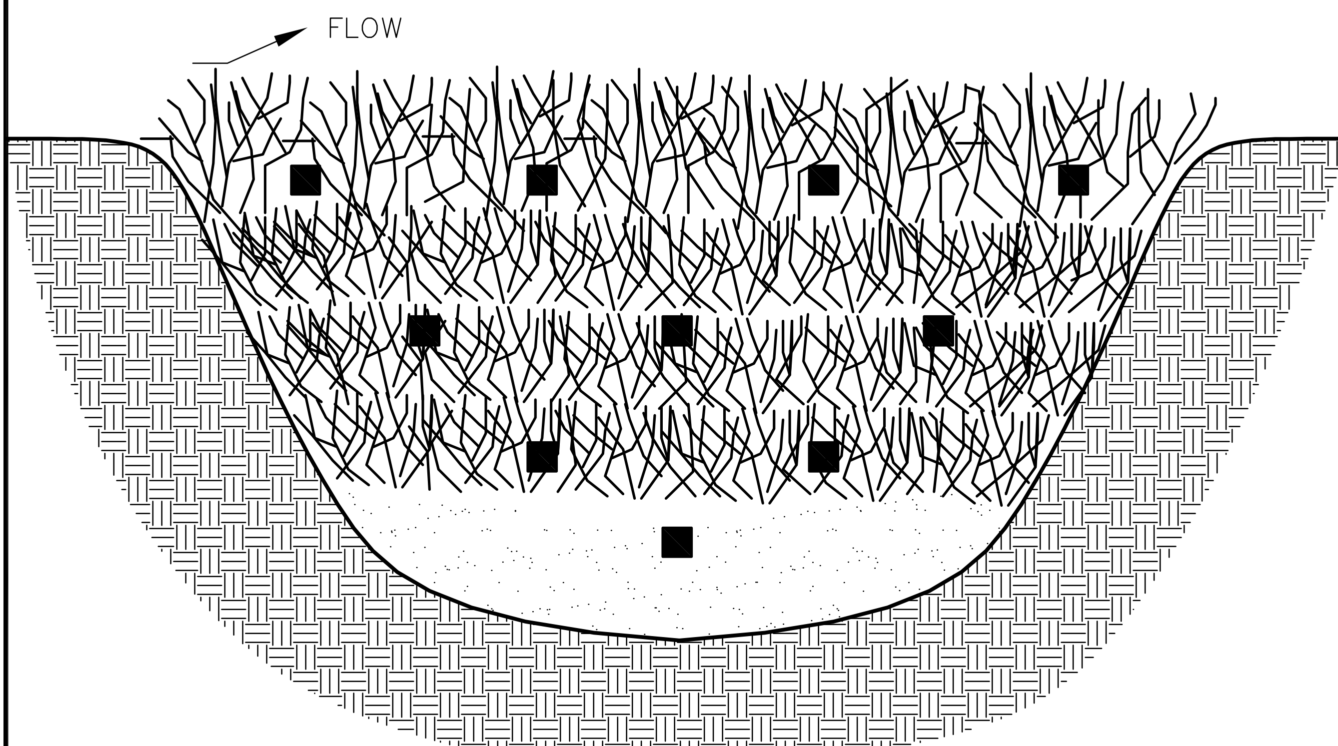
FIGURE 9-9

DETAIL OF BRANCH PACKING

(EFFECTIVE DATE 1/01/09)



SECTION VIEW
N.T.S.



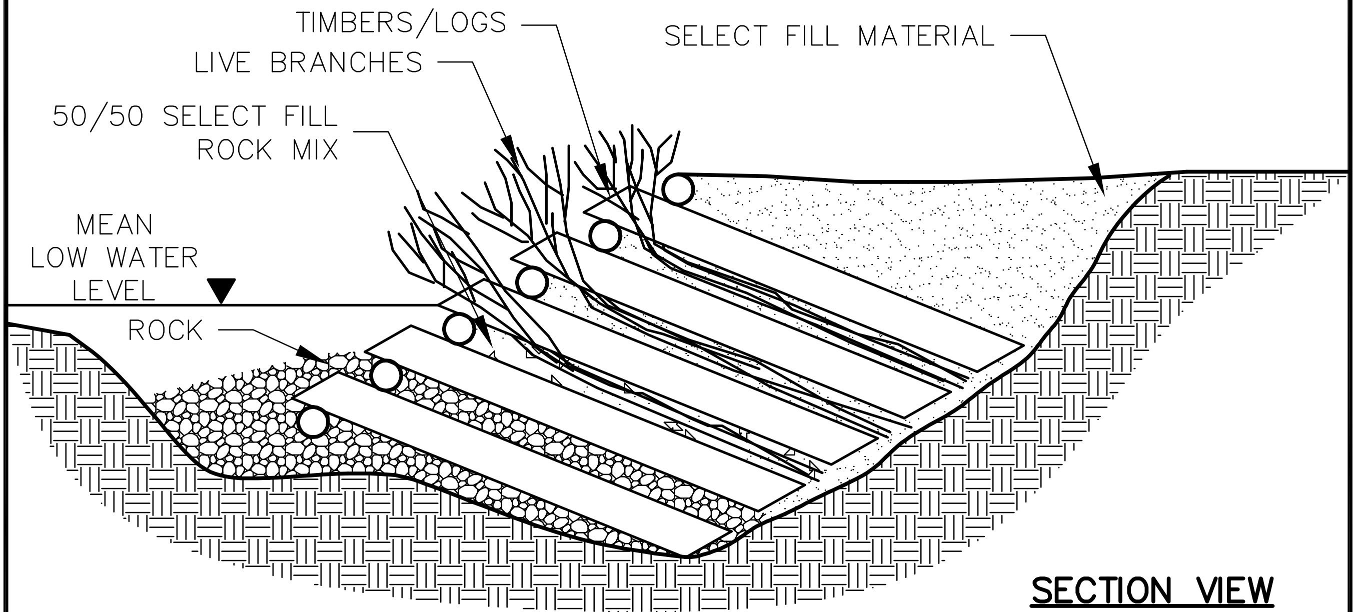
PLAN VIEW
N.T.S.

STORMWATER MANUAL

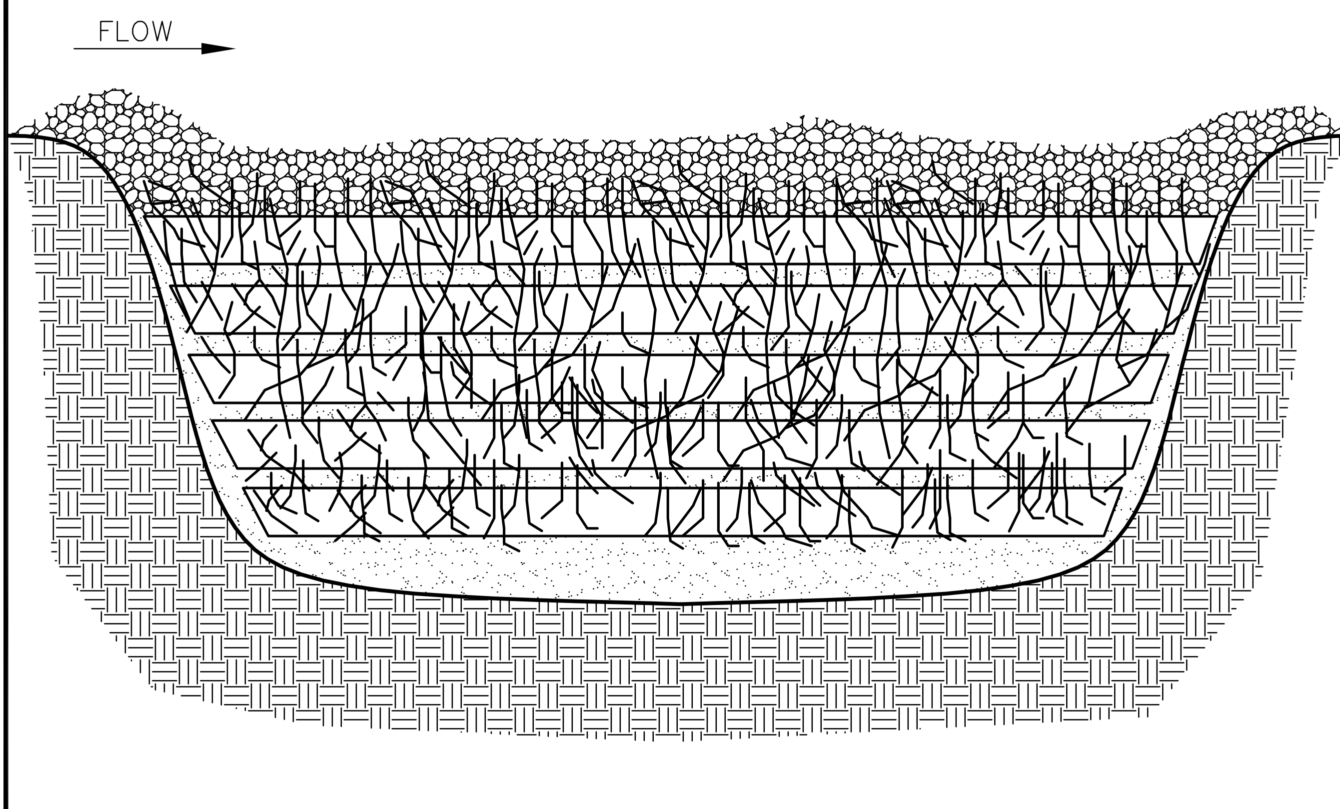
FIGURE 9–10

DETAIL OF LIVE CRIBWALL

(EFFECTIVE DATE 1/01/09)



SECTION VIEW
N.T.S.



PLAN VIEW
N.T.S.

STORMWATER MANUAL

FIGURE 9-11

DETAIL OF LOG CRIB REVETMENT

(EFFECTIVE DATE 1/01/09)